TABLE 1. Potential Mars Pathfinder landing sites.

Prior. #	Location	Lat./Long.	Elevation	Geology	MC Chart
1	Ares Vallis/Tiu Vallis	19.3°N, 35°W	−1.5 to −1 km	Fluvial dep. (delta?) (N, H, A)*	11 NW/Amazonis Planitia
10	Mawrth Vallis	27°N, 23°W	< 1 km	Fluvial dep. (delta?) (N, A)*	11 NE/Oxia Palus
11	Hypanis Valles	11.5°N, 45.5°W	0 to 1 km	Fluvial dep. (delta?) (N)*	10 SE/Lunae Palus
9	Kasei Valles	26°N, 48.5°W	−3 to 0 km	Fluvial dep. (delta) (N, H, A)*	10 NE/Lunae Palus
8	Maja Valles	17.5°N, 53°W	−1 to 0 km	Fluvial dep. (delta?) (N, H)*	10 NE/Chryse Planitia
2	Kasei Valles	21°N, 75.5°W	0 to 1 km	Fluvial and eolian mat. (N, H, A)*	10 NW/Lunae Palus
12	Arago Crater	10.2°N, 330°W	1 to 2 km	Fluvial and eolian mat. (N, A)*	12 SE/Arabia Terra
6	Marti Valles	6.5°N, 183.5°W	−1 to −2 km	Fluvial and volcanic mat.? (A)*	15 SE/Elysium Planitia
7	Marti Valles	2.5°N, 191°W	−1 to −2 km	Fluvial and volcanic mat.? (A)*	15 SE/Elysium Planitia
3	Medusae Fossae	1°N, 160°W	0 to 1 km	Eolian and volcanic mat.? (A)*	8 SW/Amazonis Planitia
4	Medusae Fossae	1°N, 146°W	1 to 2 km	Eolian and volcanic mat.? (A)*	8 SE/Amazonis Planitia
5	Lunae Planum	20°N, 61°W	0 to 2 km	Volcanic mat. (H)*	10 NE/Lunae Palus
			Mars '94/'96 Landing Sites *Small Stations*		
	Arcadia Planitia	40.6°N, 158.5°W	−1 to −2 km	Young sedimentary mat. (A)*	2SW,2SC/Diacria
	Northern Amazonia	30.5°N, 165°W	−1 to −2 km	Young volcanic mat. (A)* with eolian mantling	2SW,2SC/Arcadia
			Penetrators		
	Arcadia Planitia	38°N, 162°W	−1 to −2 km	Young sedimentary mat. (A)*	2SW,2SC/Diacria
	Arcadia Planitia	39°N, 154°W	−1 to −2 km	Young sedimentary mat. (A)*	2SW,2SC/Diacria

* N - Noachian system, H - Hesperian system, A - Amazonian system.

An advantage of Mars Pathfinder is the rover for sampling surface materials over a range of tens of meters. However, engineering constraints and the limited scientific payload of this mission require new approaches for landing site selection [1]. One approach is to select sites exhibiting a wide variety of rocks near the lander (e.g., Arago Crater, Site 12). An alternative approach is to select sites in which the regional geology consists of a single rock type representing a key datum for the geological study of Mars, and is uniformly distributed within the landing ellipse. Examples of this approach include (1) landing sites on rocks of Hesperian age, e.g., ridged plains (site 5), (2) sites that contain sedimentary deposits of Amazonian age with sharply distinct individual surface morphology, e.g., deposits of the Medusae Fossae Formation (sites 3 and 4), and (3) young volcanic deposits, e.g., Marti Vallis (sites 6 and 7).

Based on these approaches and consideration of landing safety, 12 sites were selected for Mars Pathfinder (Table 1). Of these landing sites, six sites (sites 1, 6, 7, 8, 9, and 10) are consistent with the nominal mission requirements. Three additional sites (sites 4, 5, and 12) can be considered if elevation constraints are increased to 2 km. Three other sites (sites 2, 3, and 11) are located between 0 and 1 km. Six of the sites (sites 2, 3, 4, 6, 7, and 12) are included in the area occupied by surface Unit 1 [2]. Another three sites (sites 5, 8, and 11) are located within Unit 3, and the remaining three sites (sites 1, 9, and 10) are located in the boundary zone between units 2 and 3. From the 12 proposed sites, nine sites (sites 2, 3, 4, 5, 6, 7, 8, 11, and 12) have a rock abundance of 3–8%. Three other sites (sites 1, 9, and 10) have a rock abundance of 8–15%. All selected sites are in regions with different surface roughness characteristics (meters to tens of meters scale) expressed as RMS slope values. From the 12 sites, only one site (site 3) is characterized by the highest RMS slope value (10°–15°), but exhibits the lowest values of thermal inertia (<3 × 10^{-3} cal/cm^{2}s$^{1/2}$K) and rock abundance (<6%). The remaining eleven sites have RMS values <8°.

Under nominal elevation constraints, especially with regard to Mars Pathfinder, we propose the Ares-Tiu Valles and Maja Valles delta areas (sites 1 and 8), and Marti Vallis (sites 6 and 7) as high-priority targets. If the maximum elevation constraints are increased to 2 km, the more favorable sites are the Ares-Tiu Vallis delta area (site 1), Kasei Vallis bend area (site 2), Medusae Fossae (sites 3 and 4), and Lunae Planum (site 5).

References: [1] Greeley R. and Kuzmin R., this volume. [2] Christensen P. R. and Moore H. J. (1992) in *Mars* (H. Kieffer et al. eds.), 686–729, Univ. of Arizona, Tucson.

N95-16194

A PERSPECTIVE OF LANDING-SITE SELECTION. H. J. Moore, U. S. Geological Survey, Menlo Park CA 94025, USA.

The Viking '75 Project began examining the problems of landing two spacecraft on Mars immediately after project authorization in 1969. This examination resulted in the Viking-Mars Engineering Model [1], which addresses the interplanetary, near-Mars (>60 km), atmospheric (<60 km), and surface environments and astrodynamical data.

During the Mariner 9 Mission, a Viking Data Analysis Team examined images and other data in near-real time, assessed Earth-based radar echo data, and prepared terrain maps with the intent of identifying potential landing sites [2]. No sites were identified because of uncertainties in image interpretation engendered by a hazy atmosphere, conflicting elevations from different sources, and other factors.

A Viking Landing Site Working Group was convened in early 1972 to identify site-selection criteria compatible with landing safety, system capabilities, and science objectives [3]. Among numerous criteria were low elevation (for parachute performance), large separations of site pairs (for communications), and a "warm and wet" environment (favorable for life).

Eleven landing sites between 30°N and 30°S were selected and considered by the Landing Site Working Group [4,5]. Later, six sites from about 43° to 73°N were considered because of their relative abundance of water vapor [5]. Still later, four equatorial sites were added because of existing radar data on them and their accessibility to future radar observations. Most of the sites were rejected for various reasons.

Four landing sites were approved by NASA Headquarters: (1) Chryse (prime A1; 19°N, 34°W), (2) Tritonis Lacus (back-up A2; 20°N, 252°W), (3) Cydonia (prime B1; 43°N, 11°W), and (4) Alba (back-up B2; 43°N, 110°W). The northern B sites replaced earlier southern sites (Apollinares and Memnonia) because the B sites were thought to have higher atmospheric water contents. Two equatorial sites were retained because of their radar signatures: (1) Capri (C1; 6°S, 43°W) and (2) Meridiani Sinus (C2; 5°S, 5°W).

For mission operations, the Landing Site Working Group was augmented by the Viking Flight Team and renamed the Landing Site Staff [3]. This latter group was responsible for Site Certification when the first orbiter's instruments could observe the prime site (A1) and ongoing radar observations could be analyzed; its responsibilities included certification of the second landing site. Certification criteria were much the same as those for selection: (1) landing ellipse size, (2) elevation, (3) surface temperatures, (4) geology, (5) surface roughness (slopes), (6) protuberances (rocks), (7) "soil" properties (bulk density, etc.), (8) radar reflectivity, (9) density-temperature profile of atmosphere, (10) atmospheric composition, (11) dust storms, and (12) winds.

There was no landing at any preselected site. Plans to land the first spacecraft at the initial Chryse site on July 4, 1976, were discarded because the surface, which appeared to be smooth and nearly featureless in hazy Mariner 9 images, appeared extremely rough, complicated, and eroded (and probably rocky) in the Viking images [6–8]. Arecibo quasispecular radar echoes at 12.6 cm from the vicinity of the site suggested a rough surface (RMS slopes near 5°–7°) but near-average reflectivity [9]. Small signal-to-noise ratios of Goldstone echoes (3.5-cm wavelength) from the site were particularly worrisome because they contrasted with large signal-to-noise ratios from Tritonis Lacus [9], and scenarios to explain the small ratios were all unfavorable. Other criteria appeared to be satisfied.

Viking 1 then began a search for a new site to the northwest of the original site based on images and Arecibo quasispecular radar observations [6,9]. *A priori* selection and certification of the final site were satisfying and defensible, because the project could say (1) there is evidence for abundant soillike materials in the images, (2) the rms slopes (4.5°–5.5°) are like those of lunar maria where Surveyors had landed, and (3) the reflectivity (0.07) is average for Mars [6–9]. The Viking Project made a sincere effort to find a safe landing site and was rewarded with a successful landing.

After the first lander demonstrated Viking's capabilities for entry, descent, and landing, almost everyone wanted to explore to the north, where atmospheric water vapor abundances were high [3,10]. A new northern site, Utopia Planitia (B3), was added, and orbiter temperature observations replaced the radar as a tool to assess surface material properties. Both the Cydonia (B1) and Alba (B2) sites appeared unexpectedly rough; again, Mariner 9 images taken through hazy skies had suggested smooth and mantled surfaces. B1 was rejected because large areas appeared rough and eroded; extensive "mantles" and "dune fields" were not found. B3 was chosen over a western extension of B2 because of the operational complexity that would be introduced; the modest difference in water-vapor abundance and inferred thicknesses and extents of "mantles" and "dunes" did not warrant the increased risk engendered by the increased operational complexity [3,10]. Thermal inertia at the B3 site was judged to be about the same as that of the Lander 1 site, but it was not possible to distinguish between a surface of sand and a surface like that around Lander 1 [10]. The B2 site had a lower thermal inertia than the B3 site [10]. Lander 2 was a success, but those expecting to see extensive mantling deposits or abundant sand dunes were surprised by the rocky scene.

The problems that now confront Mars Pathfinder are much the same as those that confronted Viking, but more and better information exists today. Like Viking, Mars Pathfinder must select a landing site compatible with lander and rover designs as evidenced by available data (Viking images, radar and thermal observations, albedo and color observations, visible-infrared spectra, etc.). Most regions at low elevations probably contain favorable sites, but some sites at low elevations with weak quasispecular echoes and low thermal inertias may be unfavorable [11].

References: [1] Anonymous (1974) *Viking 75 Project Doc. M 75-125-3*, 337, 1 plate, NASA Langley Research Center. [2] Anonymous (1972) *Viking 75 Project Doc. M 75-144-0*, 190, 8 maps, NASA Langley Research Center. [3] Masursky H. and Crabill N. L. (1981) *NASA SP-429*, 34. [4] Masursky H. and Strobell M. H. (1976) *Astrogeol., 59*, 76–431, 73. [5] Masursky H. and Strobell M. H. (1976) *Astrogeol., 60*, 76–432. [6] Masursky H. and Crabill N. L. (1976) *Science, 193*, 809–812. [7] Young R. S. (1976) *Am. Sci., 64*, 620–627. [8] Moore H. J. et al. (1987) *USGS Prof. Paper 1389*, 222. [9] Tyler G. L. et al. (1976) *Science, 193*, 812–815. [10] Masursky H. and Crabill N. L. (1976) *Science, 194*, 62–68. [11] Moore H. J. and Jakosky B. M. (1989) *Icarus, 81*, 164–184.

N95-16195

TARTARUS COLLES: A SAMPLING OF THE MARTIAN HIGHLANDS. S. Murchie and A. Treiman, Lunar and Planetary Institute, 3600 Bay Area Boulevard, Houston TX 77058, USA.

Several of the most fundamental issues about the geology of Mars can be addressed using information on composition and structure of the plateau plains ("highlands") that cover approximately half the planet [1,2]. The units that compose the highlands are interpreted as a mixture of volcanic, fluvial, lacustrine, and impact ejecta deposits. A more precise inventory of differing of igneous and sedimentary lithologies in highland rock units would not only lead to a better understanding of how the plateau plains formed, but would also clarify the nature of the surface environment during the first 800 m.y. of martian history. Structural features including bedforms, joints, and small faults that are unresolved from orbit record a history of the emplacement and deformation of the high-